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24.—The Effect of Frequent Burning on the Jarrah (Eucalyptus marginata) Forest Soils of Western Australia

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An examination of the surface soils from regularly burnt firebreaks and adjacent protected compartments in the jarrah forest of Western Australia showed no differences in the following analyses; pH, total soluble salts, organic carbon, nitrogen, exchangeable metal ions and exchangeable hydrogen.

It has been shown that the temperatures of these controlled burns are of the order of 320-450°C., and the forest soil is not exposed to any prolonged high temperatures.

If the burning does cause any temporary loss of organic matter and inorganic nutrients from the immediate surface soil these losses are replaced by natural leaching of the following year's leaf fall.

Introduction

In the fire protection of the jarrah (*Eucalyptus marginata*) forest in Western Australia regular controlled burning of strips of forest along railway lines, main roads, etc. is carried cut to reduce the fire risk to adjacent areas of forest. This burning is normally carried out during the latter spring months and the first half of December, and the frequency of burning of these firebreaks varies from annually to every third year, depending on the litter fall and the fire risk involved.

The forest country adjacent to the breaks has been protected from fire as completely as possible for periods ranging from 15 to 25 years, and has an Ao horizon ranging from 4½ - 6½ tons per acre (oven dry weight). By contrast the firebreaks have only a sparse accumulation of litter, which is regularly removed by burning.

The aim of this study was to compare the chemical properties of the two groups of surface soils, and to ascertain what changes had taken place in the surface soils as a result of the regular burning.

Location

The samples were collected from several areas in the Dwellingup Forest Division, which forms part of the prime jarrah forest of Western Australia.

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Climate

The jarrah forest region experiences a typical Mediterranean climate, with cool wet winters and hot, dry summers. The average annual rainfall at Dwellingup is 50.88 inches, spread over 134 days. The rainfall distribution shows a marked winter maximum, 81 per cent. of the annual rainfall occurring during the months May to September. The mean monthly temperatures vary from 69.7°F. in February to 49.4°F. in July.

Soils

The soils are typically lateritic gravelly soils with a shallow dark grey gravelly sand overlying deep yellow brown very gravelly sands. Laterite boulders occur frequently throughout the profile.

Experimental

Surface soil samples, (0-3½") were collected during January, 1954, from twelve pairs of adjacent areas, using a constant volume soil sampler. The areas were selected for similarity of topography, soil and forest vegetation. Details of the fire history of these areas are shown in Table I.

TABLE 1

Experimental Areas
Fire History

Location.	Fire History. Compartment.	Firebreak.
1. Amphion, Compt. 6	1932	Triennially.
2. Curara, Compt. 5	1930	Annually.
3. Curara, Compt. 8	1937	Triennially.
4. Holmes, Compt. 1	1929	Annually.
5. Holmes, Compt. 3	1934	Annually.
6. Holmes, Compt. 11, Plot 11	1934	Triennially.
7. Holmes, Compt. 11, Plot 13	1934	Triennially.
8. Holmes, Compt. 12	1934	Triennially.
9. Holmes, Compt. 14	1935	Triennially.
10. Marrinup, Compt. 4	1938	Annually.
11. Mt. Wells, Compt. 10	1931	Frequently.
12. Teesdale, Compt. 2	1939	Triennially.

In the soil sampling, twenty-seven individual samples were collected from each of the burnt and unburnt areas, and combined to give three composite samples from each treatment.

In the laboratory the samples were air dried, and then passed through a 2 mm sieve. The fine earth fractions were analysed for pH, total soluble salts, organic carbon, nitrogen, exchangeable metal ions and exchangeable hydrogen.

In the analysis of the soil samples, most of the methods used were those described by Piper (1942), but at a result of recent investigations a newer method was used for the determination of the exchangeable metal ions. These were extracted by leaching with neutral normal ammonium acetate, and the calcium and magnesium determined by titration with E.D.T.A. after destruction of the ammonium acetate. (Bond and Tucker 1954 and Hutton 1954). Potassium and sodium were estimated by the EEL flame photometer (Hutton and Bond unpublished data) after the ammonium acetate had been removed by gentle ignition.

Analytical Data

The means for the two groups of surface soils are tabulated in Table II, and in addition the individual means for pH, nitrogen and exchangeable calcium are shown in Tables III, IV, and V.

TABLE II

Analytical Data

Surface Soils (0-3½") from Protected Compartments and Regularly Burnt Firebreaks

Analysis	Means				Difference		P .05 Difference for Significance	
	Compartment		Firebreak					
pH	6·27		6·38		– 0·11		0·21	
Total Soluble Salts (%)	0·016		0·015		+0·001		0·005	
Organic Carbon (%)	2·96		3·00		– 0·04		0·64	
Nitrogen (%)	0·125		0·128		—0·003		0·025	
Exchangeable Cations								
Calcium m.e. %, %	3·92	67	4·23	69	—0·31	—2	1·25	4·9
Magnesium m.e.%, %	1·35	24	1·42	23	—0·07	+1	0·46	3·3
Potassium m.e. %, % ..	0·11	2	0·10	2	+0·01	0	0·03	0·4
Sodium m.e. %, %	0·35	7	0·34	6	+0·01	+1	0·11	2·6
Exchangeable Metal Cations ...	5·73	100	6·09	100	–0·36	—	1·67	—
Exchangeable Hydrogen (pH 8·4) ..	12·00		10·97		+1·03		2·70	
Total Exchange Capacity m.e. % .	17·73		17·06		+0·67		4·05	
Per cent. Metal Iron Saturation	32·1		35·5		—3·4		4·4	

It is evident from the data that this regular light burning has had no significant effect on the surface soil properties examined.

Both groups of soils are mildly acid, and low in soluble salts. Organic carbon values are relatively high, but nitrogen values are low, giving wide C/N ratios of 24 and 23 for the compartments and firebreaks respectively. These wide C/N ratios are related to the litter fall in the jarrah forest, which is very high in carbon and has a C/N ratio of approximately 100.

In both groups of soils the cation exchange capacity is almost solely dependent upon the organic matter present in the surface horizon, and is relatively low. Calcium is the dominant exchangeable cation in the surface, averaging two thirds of the total exchangeable metal ions. Magnesium is next in importance and potassium and sodium are only of minor importance in the total exchangeable metal ions.

Exchangeable hydrogen values (to pH 8.4) are relatively high, and the soils are moderately unsaturated, the percentage metal ion saturation being 32.1 and 35.5 per cent. for the compartments and firebreaks respectively.

Discussion

There do not appear to be any Australian data available on the effects of fire on the Eucalypt forest soils, and it is difficult to compare the jarrah forest conditions with those quoted by overseas workers.

From a study of the literature it appears to be generally accepted that a very hot fire, such as a slash burn, where fire temperatures are of the order of 850°C. for a prolonged period, has a significant effect on soil properties. Under these conditions there is usually a decrease in organic matter, loss in nitrogen and increase in pH in the surface soils.

However, opinions differ very widely when considering the effects of light and moderate burns on the soil properties.

One group of workers claim that burning has a detrimental effect on the soil. Amongst these are Worley (1933) who stated:

(i) that burning destroyed humus.

(ii) that resultant ash from the burn, containing small amounts of essential elements such as copper and manganese, is easily lost through leaching and a general impoverishment results.

Freise (1939) claimed that repeated burning had an unfavourable effect on the physical and biological properties of the soil, and Elwell and Fenton (1941) stated that burning caused a loss of soil nitrogen, destroyed organic matter and increased soil and water losses.

A second group of workers believe that burning has no significant effect on the soil. Amongst these are Alway and Rost (1928) who suggested that burning appears to be neither beneficial nor detrimental to the soil, and Blaisdell (1953), who claimed that light and moderate burns do not affect soil properties.

TABLE III

Analytical Data

Surface Soils (0-3½") from Protected Compartments and Regularly Burnt Firebreaks

pH Values

Location	Mean Values		Difference
	Compartment	Firebreak	
Amphion, Compt. 6	6·47	6·54	0·07
Curara, Compt. 5	6·27	6·48	—0·21
Curara. Compt. 8	6·26	6·47	—0·21
Holmes, Compt. 1	6·57	6·50	+0·07
Holmes, Compt. 3	5·85	5·93	—0·08
Holmes, Compt. 11, Plot 11 ..	6·19	6·27	—0·08
Holmes, Compt. 11, Plot 13 ...	6·49	6·17	+0·32
Holmes, Compt. 12	6·16	6·34	—0·18
Holmes, Compt. 14	6·24	6·36	—0·12
Marinup, Compt. 4	5·72	6·27	—0·55
Mt. Wells, Compt. 10 ...	6·47	6·86	—0·39
Teesdale, Compt 2	6·54	6·41	+0·13
Means	6·27	6·38	—0·11

P ·05 difference for significance = 0·21.
Each value shown is the mean of three composite samples.

The third group believe that light and moderate burning has a favourable effect on the forest soil. One of the most important papers in this group is that of Heywood and Barnette (1934), who showed that soils frequently subjected to fire were consistently less acid, and had higher percentages of exchangeable calcium and total nitrogen. Also Burns (1952) found that moderate burning benefited the mineral soil chemically, and probably had a favourable effect on the forest floor, and in 1955 Vlamis, Schultz and Biswell demonstrated by means of pot experiments that light burning increased the nitrogen power of the soil fourfold, and in addition tended to increase the phosphorus supplying power of the soil.

TABLE IV

Analytical Data

Surface Soils (0-3½") from Protected Compartments and Regularly Burnt Firebreaks

% Nitrogen Values

Location	Mean Values		Difference
	Compartment	Firebreak	
Amphion, Compt. 6	0·120	0·132	– 0·012
Curara, Compt. 5	0·122	0·144	– 0·022
Curara, Compt. 8	0·152	0·179	– 0·022
Holmes, Compt. 1	0·090	0·122	—0·022
Holmes, Compt. 3	0·121	0·115	+0·006
Holmes, Compt. 11, Plot 11....	0·079	0·097	– 0·018
Holmes, Compt. 11, Plot 13....	0·097	0·157	0·060
Holmes, Compt. 12	0·137	0·095	+0·042
Holmes, Compt. 14	0·100	0·142	—0·042
Marrinup, Compt. 4	0·176	0·094	+0·082
Mt. Wells, Compt. 10	0·122	0·126	0·004
Teesdale, Compt. 2	0·184	0·132	+0·052
Means	0·125	0·128	—0·003

P ·05 difference for significance – 0·025.
Each value shown is the mean of three composite samples.

It is evident that the data for the jarrah forest soils strongly supports the second group of workers in that there were no significant differences in the surface soil properties examined.

With regard to the effect of the control burn on the forest crop it has been shown by Harris (1956) that the best of the older jarrah saplings are found alongside the old bush tramways, where fires were set by the locomotives as often as a fire would run. In addition Loneragan, (unpublished data) and Harris (1956) have shown that there is no significant difference in girth increments between saplings on regularly burnt firebreaks and protected compartments.

In considering the effects of the controlled burnings of the jarrah forest soil there are several factors which appear to be related to the lack of differences between the two groups of soils.

Firstly, the temperature of the burn is not high, and in some experiments carried out at Dwellingup, it was found that the temperatures of a controlled burn were of the order of 320°-450°C. for two and three year old litter. Secondly, the litter on the firebreak consists mainly of leaves and fine twigs, and thus burns rapidly. Therefore, the soil is not exposed to prolonged high temperatures in the controlled burn. In connection with this work it has been shown by Heywood (1938), that in the Longleaf Pine region of Southern U.S.A., the heat from the majority of forest fires is insufficient to impoverish the soil, and that the slight heat which enters the soil during the fire may even favour plant nutrition.

TABLE V

Analytical Data

Surface Soils (0-3½") from Protected Compartments and Regularly Burnt Firebreaks

Exchangeable Calcium

Mean Values

(m.e.% & %)

Location	Compartment		Firebreak	
Amphion, Compt. 6	3·08	67	5·08	66
Curara, Compt. 5	4·34	69	3·11	63
Curara, Compt. 8	5·66	71	8·34	72
Holmes, Compt. 1	2·78	72	3·58	73
Holmes, Compt. 3	3·58	65	3·80	66
Holmes, Compt. 11, Plot 11	1·65	58	1·96	62
Holmes, Compt. 13, Plot 13	2·47	63	4·41	69
Holmes, Compt. 12	4·69	66	5·08	76
Holmes, Compt. 14	3·13	63	3·56	68
Marrinup, Compt. 4	5·34	65	3·27	73
Mt. Wells, Compt. 10	4·69	77	3·32	71
Teesdale, Compt. 2	5·58	75	5·24	69
Means	3·92	67·6	4·23	69·0

P ·05 difference for significance = 1·25 m.e. % and 4·9%.
Each value shown is the mean of three composite samples.

In addition the controlled burning is carried out during the latter part of the year, and the maximum leaf fall in the jarrah forest occurs during the months of January, February and March. In jarrah regrowth forests the leaf fall during this period may amount to between 12 and 15 cwt. per acre (o.d.wt.), and this leaf litter contains the following amounts of inorganic nutrients; 0.77% calcium, 0.240% magnesium, 0.252% potassium and 0.473% nitrogen.

The fresh leaf litter on the forest floor of the firebreak is exposed to at least one winter's leaching by the rainfall, and it has been shown by Hatch (1955) that jarrah leaf litter loses one third of its oven dry weight during the first winter. This loss in weight includes the majority of the inorganic actions and a considerable amount of readily soluble organic compounds, and evidently this accession of nutrients and organic compounds from the litter is sufficient to replace any losses in the immediate soil surface which may be caused by the burning.

In field inspections of the firebreaks and compartments, the chief differences observed were the absence of a thick A1 horizon in the firebreak soils and also the undergrowth vegetation appeared to be much sparser in the firebreaks.

Conclusion

It is evident that the practice of regularly burning selected firebreaks in the jarrah forest has had no significant effect on the soil properties examined, and the results support the conclusions of Alway and Rost (1928) and Blaisdell (1953).

Also, from the above data, it would appear that the Departmental policy of prescribed controlled burning, which is primarily based on practical and economic considerations related to the present stage of development of this State, is unlikely to cause any soil deterioration to take place.

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